JP1.4 VALIDATION OF NSIPP TIER-2 SEASONAL FORECASTS: WHAT CAN WE GAIN FROM IMPROVED SST FORECASTS?

P.J. Pegion[*1], S.D. Schubert[2], M.J. Suarez[2]
NASA Seasonal-to-Interannual Prediction Project

1. INTRODUCTION

An assessment of seasonal predictability has typically been carried out with atmospheric general circulation models (AGCMs) forced with observed sea surface temperatures (SSTs). The uncertainty in the forecasts is assumed to arise from the imperfectly known atmospheric initial conditions. Predictability is measured by generating multiple runs with the same SST but with perturbed initial atmospheric conditions. Such experiments provide an upper bound on atmospheric predictability given "perfect" SSTs. Less work has been done to assess the impact of uncertainties in SST (see, however, Goddard et al. 2001).

In this study, we examine the impact of uncertainties in SSTs based on an operational suite of seasonal forecasts that have been carried out over the last 10 months with the NASA Seasonal-to-Interannual Prediction Project (NSIPP) version 1 (Bacmeister et al. 2000) atmospheric general circulation model (AGCM). The NSIPP-1 AGCM forecasts are typically carried out once a month using two different SST forecast products (described below). In addition, "perfect SST" hindcasts are carried after the validation period, using observed SSTs.

2. THE NSIPP FORECAST SYSTEM

The NSIPP forecasts are carried out using the so-called two-tiered approach. In this approach, the forecasts are produced in two stages. The first stage (Tier-1) generates the SST forecasts using, for example, a fully coupled atmosphere-ocean-land model, or perhaps a simple statistical model. These SST forecasts are then used, in the second stage (Tier-2), to force an atmospheric (and land) general circulation model (AGCM).

1. SAIC-GSO Beltsville, MD
2. NASA GSFC, Greenbelt, MD

* *Corresponding author address*:
Philip J. Pegion
NASA Goddard Space Flight Center
Mailstop 913.0
Greenbelt, MD 20771
e-mail: pegion@janus.gsfc.nasa.gov

Routine forecasts with the NSIPP-1 system began in January 2001. For these runs, the Tier-2 NSIPP-1 AGCM forecasts are forced with the Tier-1 SST forecasts generated by the NSIPP coupled model (note that the coupled model uses an earlier version of the AGCM). Then, beginning in March 2001, an additional suite of forecasts was started in which the NSIPP-1 AGCM is forced by SST forecasts obtained from the International Research Institute (IRI). These forecasts are part of a collaborative project with the IRI.

The NSIPP-1 AGCM is a finite difference model run here with a 2.5-degree longitude by 2-degree latitude resolution in the horizontal, and 34 levels in the vertical. Details about the model can be found in Bacmeister et al. (2000). The atmospheric model is coupled to a fully interactive land model (Koster and Suarez 1992, 1996), and can be run in stand alone mode (with prescribed SSTs) or coupled to an ocean model.

2.1 Tier-1 SST forecasts

One set of tier-1 forecasts is generated by the NSIPP coupled atmosphere-land-ocean model. For these forecasts, the AGCM is typically one generation behind that used in the tier-2 forecasts – this is largely due to the longer development time required for the coupled model. The ocean model is quasi-isopycnal with 2/3-degree latitude and 1-degree longitude resolution in the horizontal and 20 layers in the vertical. The model is described in Borovikov et al. (2000). An optimum interpolation scheme assimilates tropical atmosphere-ocean (TAO) temperature observations into the model for 45 days before the coupled forecasts begin.

Ensemble members are initialized three days apart and a total of nine ensemble members are generated for each forecast period.

The second set of SST forecasts is obtained from the International Research Institute (IRI). The NSIPP-1 AGCM seasonal forecasts generated with these SSTs are used by the IRI as part of their net assessment activities. The IRI product consists of a single SST forecast that is produced

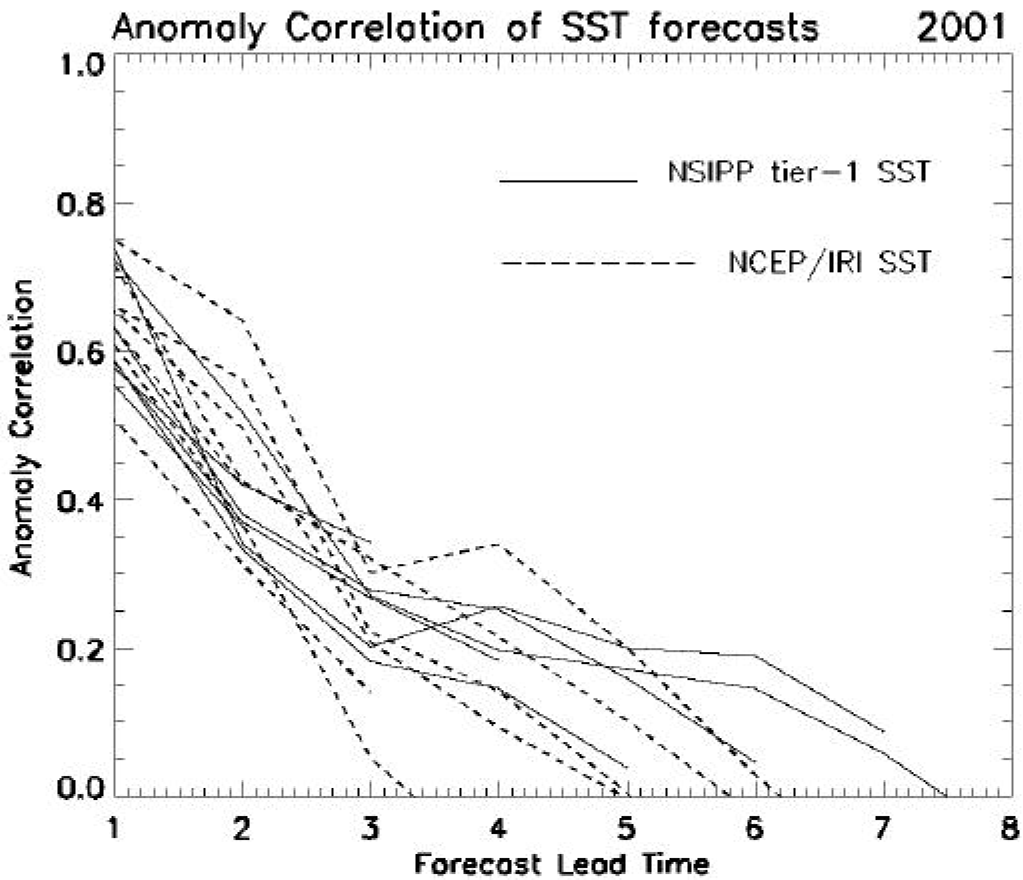

Fig.1 Spatial anomaly correlation of forecast SST equator-ward of 30-degrees latitude. Correlation is with respect to Reynolds and Smith (1994) SST.

by blending the NCEP coupled model forecast for the tropical Pacific with statistical forecasts for the other tropical oceans. Outside of the tropical oceans, SST anomalies are persisted and damped to zero over time. The SST anomalies are then added to the base period of 1961-1990 to generate the SSTs used in the NSIPP-1 AGCM forecasts. The period of 1961-1990 is used to be consistent with other forecasts generated by the IRI.

2.2 Tier-2 Atmosphere-land forecasts

a. Tier-2 forecasts using NSIPP SSTs

The NSIPP coupled model generates, for each period, a nine-member ensemble of SST forecasts. The different ensemble members are generated by initializing from different start dates. SST anomalies are produced and added to a 1980-1999 SST climatology (Reynolds and Smith 1994) for use in the Tier-2 forecasts. Initial conditions for the upper-air fields are taken from the NCEP/NCAR reanalysis valid on the 15th of the month. Land initial conditions are taken from one member of an on-going and up-to-date 9-member set of AMIP-style (forced with observed SST) simulations. The nine tier-1 SST forecasts are used to generate nine 10-month tier-2 forecasts (the first fifteen-days are treated as spin-up and discarded).

b. Tier-2 forecasts using NCEP/IRI SSTs

In this case, the Tier-2 forecasts are forced by a single SST forecast (described above). Nine member ensembles are generated by initializing the atmosphere and land using the 9-member AMIP runs mentioned above. The first month of the run is discarded as spin-up and 6-month forecasts are made.

c. Tier-2 hindcasts using observed SSTs

The SST used to force the AMIP runs are from Reynolds and Smith (1994). On the first Monday of

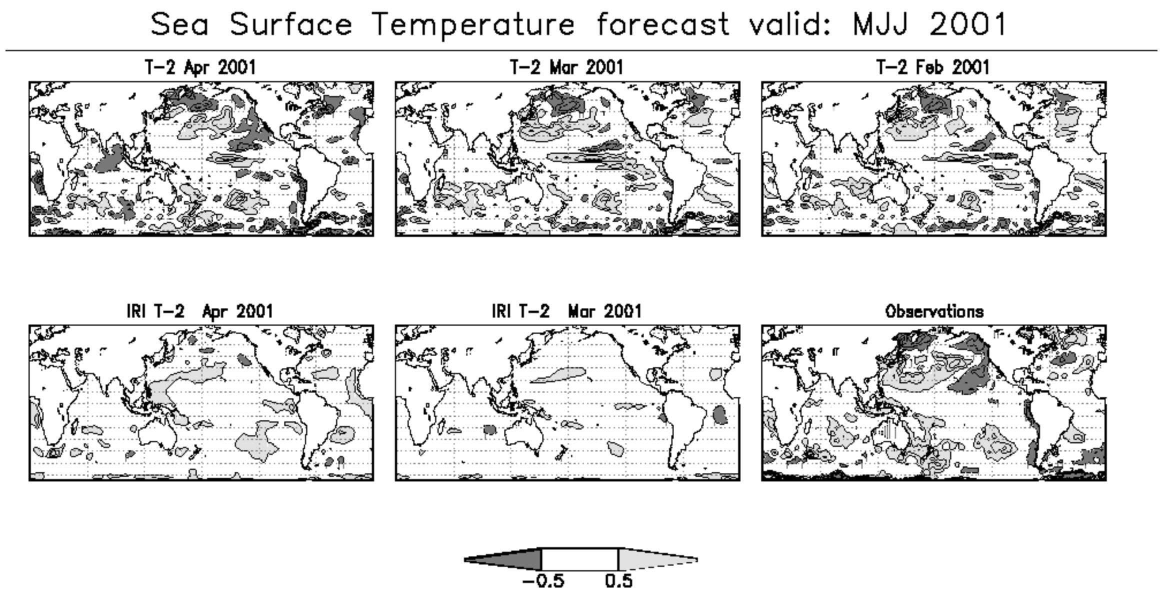

Figure 2. Global SST forecast. Upper panels are from NSIPP tier-1 forecasts. Lower left and lower middle are from the NCEP/IRI SST forecast. Lower right is the Reynolds and Smith (1994) SST anomaly. Contour interval is 0.5 C. Lighter/Darker shading indicates Positive/Negative anomalies greater that 0.5 C. Anomalies are valid for May, June, and July 2001 seasonal mean. Anomalies are based on the 1980-1999 climatology.

each month (month m) the previous months SST (month m-1) is processed and the AMIP run is integrated to the 15th of month (m-2). The AMIP runs are one month behind the calendar date because the model needs to see the next month's SST to interpolate in time between the months.

3. RESULTS

The seasonal forecasts are validated against observed precipitation (Huffman et al. 1995), and surface temperature and upper air height fields from the NCEP/NCAR reanalyses (Kalnay et al. 1995).

While our focus is on the impact of the SST, initial anomalies in the soil moisture and atmosphere can also contribute to forecast skill. For these runs, the soil is initialized from the AMIP simulations, so any signal in the soil from the observations must enter indirectly, through the observed SSTs. Also, memory of the atmosphere may enter into the skill from the Tier-2 forecasts generated with the NSIPP coupled model SSTs- for these forecasts the atmosphere was initialized from the NCEP/NCAR reanalyses.

3.1 The SST forecasts

Figure 1 shows that both the NSIPP-1 Tier-1 forecasts and the NCEP/IRI SST forecasts lose all predictability in about three months. The SST spatial anomaly correlations in Figure 1 are computed from monthly averages for the region equator-ward of 30 latitude. For the NSIPP tier-1 forecasts the correlation is computed for the ensemble mean. The anomalies are shown as a function of lead time and the different curves (for either the NSIPP or NCEP/IRI forecasts) correspond to different start dates.
The spatial patterns of the forecast anomalies show that the large scale SST (figure 2) patterns are similar to the observed. These anomaly patterns begin to develop after several months lead time. Warm anomalies in the North Central Pacific begin to show up as early as February in the SST forecasts. The NCEP/IRI forecast has a similar pattern in the extra-tropical pacific but the anomalies are much weaker. Over forecasting of an El Nino is evident in the NSIPP tier-1 forecasts whereas the NCEP/IRI SST product shows neutral conditions in the equatorial Pacific.

3.2 Atmospheric Analysis

Forecasts of surface temperature for the United States (Figure 3) shows that the warm summer in the west was reasonably well predicted. While the

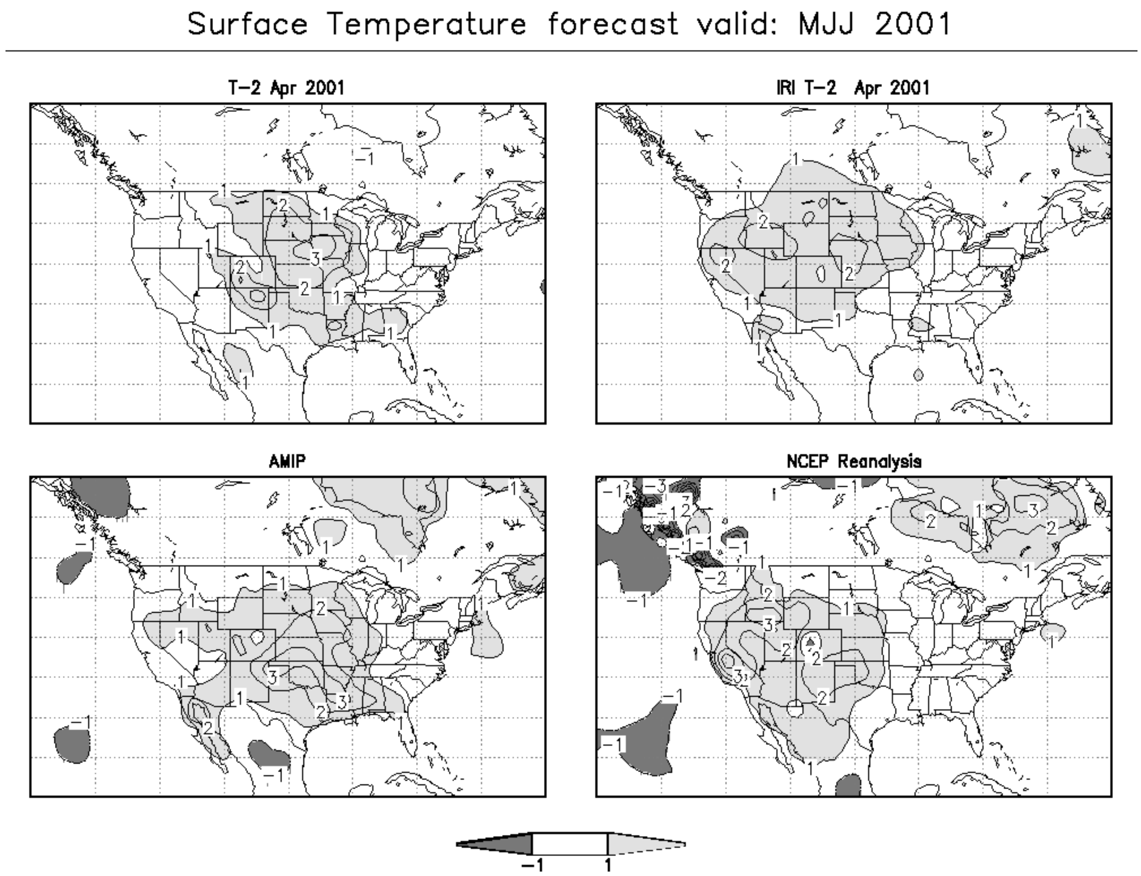

Figure 3. Top panels are May June and July 2001 surface temperature anomaly forecasts. Bottom left panel is the ensemble mean of the AMIP-style runs forced with observed SST. Bottom right is the observations/analysis. Anomalies are based on the 1980-1999 climatology

forecast anomaly patterns are shifted somewhat to the east with respect to the analysis, and the anomalies are weak, the similarities between the forecasts suggest that there is something forcing the temperature pattern.

In light of the strong drop in correlation in the SST forecasts shown in Figure 1, it is unclear what is forcing the signal in the U.S surface temperature. To see what SSTs could be driving this anomaly pattern, we compute (using our 9 AMIP simulations for the period 1961-99) the temporal correlation of the ensemble mean western U.S. temperature with the ensemble mean global model temperature at every grid point. The results of the calculation are shown in Figure 4. High correlations are evident in the equatorial cold tongue region of the Pacific Ocean that resemble the El Nino/Southern Oscillation (ENSO) signal. A lobe of high correlation stretches into the North Pacific Ocean, which suggests a tie with the Pacific Decadal Oscillation (PDO). An inspection of the SST forecasts (Figure 2) shows that there is little ENSO signal in the forecasts, while there is some evidence of a PDO-like signal that is consistent with the warm anomalies in the US.

An inspection of the atmospheric height field shows a zonally-symmetric anomaly pattern that has been shown to impact the climate of the U.S. during the summer (Schubert et al 2001).

4. CONCLUSIONS

The skill of the forecast tropical SST used to force the Tier-2 forecasts drops off rapidly during the first 3 months during the first half of 2001. Never the less, the large-scale surface temperature pattern over the western half of United States is forecast reasonably well.

An analysis of the link between the simulated MJJ surface temperature over the western 2/3 of the United States and SST (based on 30 years of AMIP

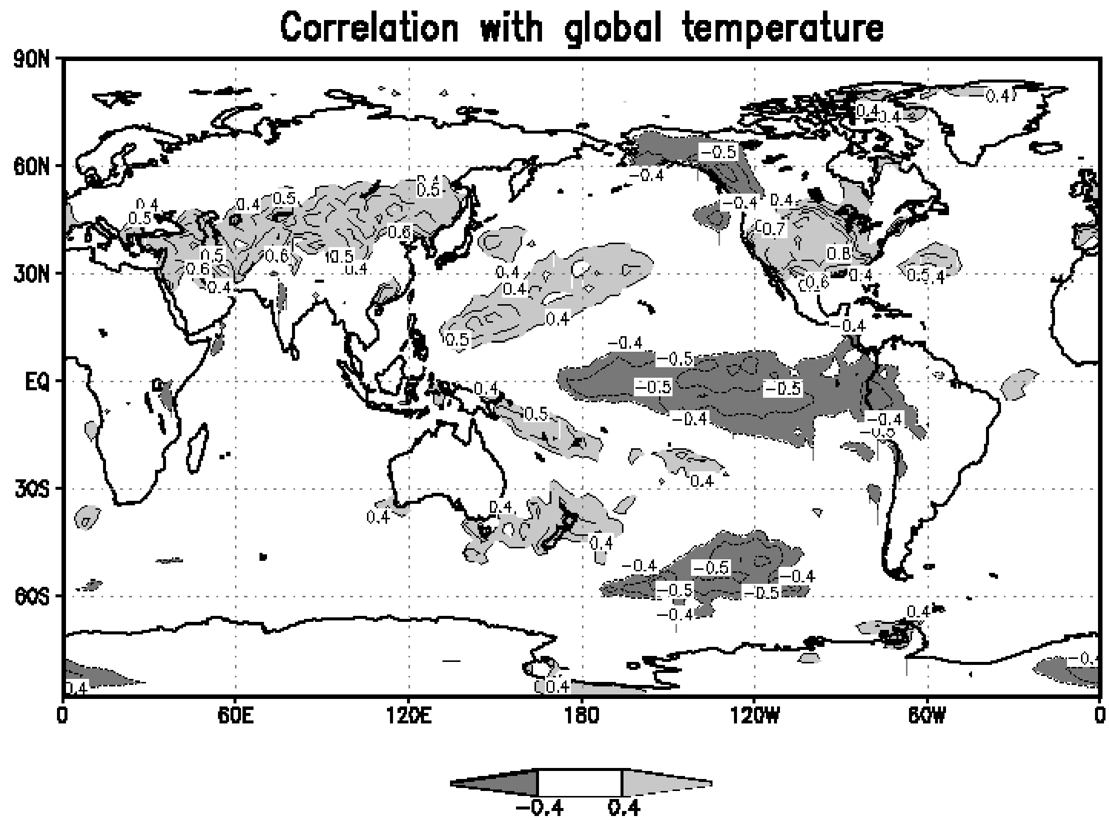

Fig. 4 Correlation of global surface temperature and average temperature over to western 2/3[rd] of the U.S. Temperatures over land are modeled, SST is observed. Correlations are fore the 1961-2000 MJJ ensemble mean

simulations) shows a very large-scale pan-Pacific SST signal. All the predicted (Tier-1) SST anomalies appear to have a projection on this broad scale pattern that is weak, but sufficient to force a warming over the United States.

Work is on-going to assess those parts of the SST that are important for generating the response over the United States, as well as to assess potential interactions with the soil conditions.

REFERENCES

Bacmeister, J., P. Pegion, S. Schubert, and M. Suarez, 2000: Atlas of Seasonal Means Simulated by the NSIPP-1 Atmospheric GCM, *Technical Report Series on Global Modeling and Data Assimilation,* **17**.

Borovikov, A., M. M. Rienecker, O. S. Schopf, 2000: Surface Heat Balance in the Equatorial Pacific Ocean: Climatology and the Warming Event of 1994-1995, *Journal of Climate,* **14,** 2624 -2641.

Goddard, L., S. J. Mason, 2001: Sensitivity of Seasonal Climate Forecasts to Persisted SST anomalies, *Submitted to Climate* Dynamics.

Huffman, G.J.,R. F. Adler, B. Rudolf, U. Schneider, and P. R. Keehn, 1995: Global Precipitation Estimated Based on a Technique for Combining Satellite-Based Estimates, Rain Gauge Analysis, and NWP Model Precipitation information, *J. Climate.* **8,** 1284-1295.

Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, J. Derber, L. Gandin, S. Sara, G. White, J.Wollen, Y. Zhu, M. Chelliah, W. Ebisuzake, W. Higgins, J. Janowiak, K. C. Mo, C. Ropelwski. J. Wang, Leetma, R. Reynolds, R. Jenne, 1995: The NCEP/NCAR

40-Year Reanalysis Project, *Bull. Amer. Meteor. Soc.,* ***77****, 437-471.*

Reynolds, W. R. and T. M. Smith, 1994: Improved global sea surface temperature analyses using optimum interpolation, *J. Climate*, **7**, 929 -948.

Schubert, S. D., M. J. Suarez, P.J. Pegion, M. A. Kistler, A. Kumar, 2001: Predictability of zonal means during boreal summer, Accepted for publication in *J. Climate*.